Guidelines on
How to Perform a Nondegradation Analysis

NonDegradation Attachments

1: Nitrate Sensitivity Analysis Spreadsheet

2: Modified Cooper-Jacobs Equation

3: Ground Water Gradient & Flow Direction Calculations - Three Point Solution Worksheet

4: Allowable Nitrate Levels

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I General Information

A) Is it a New or Increased Source?

1) A nondegradation determination must be done on a new or increased source. A new or increased source (ARM 17.30.702(16)) means an activity resulting in a change of existing water quality occurring on or after April 29, 1993.

2) This has been interpreted by EHS to mean nondegradation review will be required if: 1) there is a change in an approved drainfield location, or, 2) a new or increased (adding bedrooms) septic flow is requested in a non-DEQ reviewed and approved subdivision.

B) Nondegradation Information needed on Lot Layout

1) Mixing Zones drawn correctly (length, dispersion angle, etc.) must be shown on the lot layout for both the primary and replacement drainfields (see Mixing Zone Section for standard mixing zone parameters).

2) The location of all wells and their zone of influence must be shown on the lot layout, including nearby, off-site wells.

a) Existing wells, proposed wells AND their zone of influence (typically 100 feet) are not allowed to be located in a mixing zone per ARM 17.30.508(2).

3) Putting a readable scale and north arrow on every map is important. Make sure that the scale matches the drawing, i.e. if you reduce or enlarge something change the scale on the drawing.

C) Consideration of Nearby Developments for Cumulative Effects

1) ARM 17.30.715(2)(a) states that EHS may determine that there is a significant change in water quality resulting from cumulative impacts.

2) The nitrate sensitivity and phosphorous breakthrough calculations are conducted for each proposed drainfield and should account for cumulative effects of consecutive drainfields (in the direction of ground-water flow) in the vicinity of the proposed development. Drainfields and other sources located within nearby properties should be included in the cumulative effects analysis.

II Nitrate Sensitivity Analysis (NSA)

A) General NSA Information

1) Hydrogeologic parameters (hydraulic conductivity, hydraulic gradient, etc.) should be determined from on-site or near site data. Using wells that are not located within the proposed development to determine hydrogeologic parameters is acceptable if the wells are in the same shallow ground-water unit as exists beneath the site. The distance to an applicable well log varies from site to site depending on the potential geologic variability and on the availability or absence of well logs closer to the proposed development.

2) EHS uses the most accurate and reliable data that EHS is aware of at the time of the proposal review.

3) Shallowest Groundwater

a) All of the hydrogeologic information submitted should be related to the shallowest ground water beneath the site because the shallowest ground water is the water that will be impacted by the drainfield effluent. All state water is required to be protected from degradation. This is not limited to water that is being used locally for consumption. In many areas, the aquifer of choice for potable water is not the shallowest ground water beneath the site. Hydrogeologic information from the deeper ground-water source is not applicable to the nitrate analysis.

b) The presence of shallow ground water at a certain subsurface horizon may be disputed for some sites; therefore a test well may be required to determine the location of the shallow ground water. If required, the test well(s) shall be constructed and monitored according to the following procedures.

i) The well should be drilled, if possible, without drilling fluids. Drilling fluids interfere with the ability to recognize water-bearing materials;

ii) An engineer or geologist shall be on-site to observe drilling and to collect and classify drill cuttings by a standardized method such ASTM or USDA soil classification systems;

iii) The well should be drilled into the upper 15 feet of the shallowest water-bearing unit (or less if the water-bearing unit is less than 15 feet thick), or down to a maximum depth as determined by EHS;

iv) The well shall be completed as an open-hole or install 15 feet of perforated pipe or manufactured screen into the geologic material most likely to be water-bearing; and

v) If water is not immediately evident in the well, the well shall be covered to prevent surface water from entering the borehole and the presence of ground water shall be re-checked at least 24 hours after the well installation was completed.

c) If ground water has entered the well, the nondegradation analysis will be based on the ground water intercepted by the test well. If the well does not encounter ground water, the shallowest ground water is below the bottom of the test well, and will be based on other information.

4) Bauman Schafer Model

a) The most common model used by EHS to calculate the concentration of nitrate at the end of the mixing zone is the Bauman Schafer model (Attachment K-1). This is a model that is based on calculating the amount of dilution that will occur in the groundwater. The standard groundwater mixing zone rules (ARM 17.30.517(1)(d)(v)) do not allow for a decay (i.e. a reduction in quantity) of nitrate in a standard groundwater mixing zone as it moves through the unsaturated zone. A source specific mixing zone (ARM 17.30.518) can be requested if the applicant wishes to deviate from the standard mixing zone.

b) The Bauman Schafer model accounts for the variables discussed in ARM 17.30.517 (1)(d)(i) and for the mixing zone dimensions. EHS recommends the use of the Bauman Schafer model in nonsignificance determinations due to the simplicity of relevant data collection for the model. EHS will review and comment on other methods that may be applicable for use in the nonsignificant determinations. EHS will review and determine the applicability of other methods submitted.

c) EHS may refer other methods submitted to MDEQ or other authorities for review as necessary.

B) Hydraulic Conductivity

1) Modified Cooper Jacobs Equation for Well Logs (Attachment K-2 from Driscoll(1986))

a) Well logs are available from Montana Bureau of Mines and Geology Groundwater Information Center: *http://mbmggwic.mtech.edu* or by calling (406)496-4336.

b) Typically it is better to average as many applicable well logs as possible to give a better approximation of the hydraulic conductivity. Normally, a minimum of three well logs are required to determine an average hydraulic conductivity. However, remote sites may have fewer well logs available and will be based on fewer than three well logs. Conversely, EHS may request more than three well logs for complex sites.

c) The Modified Cooper-Jacobs Equation is only applicable to well log yield tests or drawdown tests, proper pumping tests should be analyzed by an appropriate method such as the Cooper-Jacob straight-line method or the Theis curve-matching method.

d) Many existing domestic wells are not completed in the shallowest aquifer; therefore, locating adequate logs is not always possible. When existing data are not available, EHS may require that an on-site or near-site test well be constructed.

2) Drawdown Tests

a) If a pumping test is done on a well where just the static water level and maximum drawdown level is measured then this information should be used in the Modified Cooper-Jacobs equation to determine hydraulic conductivity. This hydraulic conductivity should then be averaged with all other applicable (see comments above for well logs) hydraulic conductivity values to get the average values for use in the Bauman-Schafer model.

i) Note that many of the requirements of a pumping test also apply to drawdown tests. For example, the well should be pumped at a constant rate for the length of the pump test and the drawdown should be measured after it has stabilized.

3) Pumping and Slug Tests

a) Pumping tests can be conducted on existing wells completed in the shallowest ground water or a new well can be completed in the shallowest ground water to determine the hydraulic conductivity (each well used for a pumping test must have a complete well log to be acceptable). A pumping test can be conducted on a single well or with two or more wells (a pumping well and nearby observation well(s)) completed in the same ground-water unit. Use of an observation well during the test typically provides higher estimates of hydraulic conductivity because well inefficiency does not usually affect the results from an observation well. Typically, one pumping test will be sufficient for a proposed development. However, multiple pumping tests on different wells may be required for areas where the aquifer properties may change across the proposed development. The following criterion shall be followed when conducting a pumping test:

i) The test shall be conducted at a constant pumping rate, stepping the test or allowing the pump rate to decrease during a test will likely invalidate the results;

ii) The test shall be conducted at a pumping rate that will sufficiently stress the aquifer to create an adequate drawdown curve that can be analyzed via the Cooper-Jacob straight-line method or the Theis curve-matching methods or other accepted and appropriate methods. The pumping rate should be measured several times in the first hours of the test and at least every 6 hours, thereafter;

iii) The test duration will depend on site specific conditions including aquifer type, lithology, and size of development. EHS will require a minimum and maximum time limit with a stabilized drawdown requirement if the test is to be stopped prior to the maximum time limit;

iv) Recovery data shall be collected immediately after the pump has been turned off, the length of recovery data depend on the pumping test duration and the rate at which recovery occurs;

v) Water level data during the drawdown and recovery phases shall be collected to the nearest 0.01 foot, the recommended time intervals are listed below:

Table 1
Recommended Time Intervals

Time Since Pumping Started/Stopped	Minimum Time Between Measurements
0-3 minutes	10 seconds
3-10 minutes	30 seconds
10-30 minutes	2 minutes
30-100 minutes	5 minutes
100-300 minutes	30 minutes
300+ minutes	60 minutes
Shorter intervals may be required immediately after the pump is started or stopped	

vi) Static water levels shall be measured prior to the test;

vii) Pumped water shall be diverted sufficiently far downgradient from the pumping well and monitoring wells so as to not recharge the well(s) during the test and should not discharge into state surface waters (if water is discharged into a state surface water a discharge permit may be required from EHS); and

viii) The aquifer thickness used to calculate hydraulic conductivity is dependent on site-specific conditions. As a general guideline, the aquifer thickness used in analyzing a long-term pumping test is usually equal to the difference between the total well depth and the static water level for an unconfined or semi-confined aquifer.

b) Slug tests are an acceptable method for determining hydraulic conductivity, but they typically give lower hydraulic conductivity values than pumping tests. Slug tests are only acceptable on wells completed in the shallowest aquifer. Slug tests only affect a small area of the aquifer immediately surrounding the well (unlike pumping tests which stress large portions of the aquifer) and provide a hydraulic conductivity value for a limited aquifer area. Depending on the size of the proposed development and site hydrogeology, multiple slug tests may be required to accurately determine the hydraulic conductivity.

i) To accurately analyze the data, any well used for a slug test shall have at least a one-foot screened, perforated, or open-hole interval. Wells completed as open bottom (also known as open casing) are assumed to have a one-foot open-hole interval for use in the equations (the difference between an open-bottom and an open-hole well is that an open-bottom well is completed with solid casing to the bottom of the borehole, whereas in an open-hole well the borehole extends below the bottom of the casing). Each well used for a slug test must have a complete well log to be acceptable. The following criterion shall be followed when conducting a slug test:

1) A rising head (slug out) or falling head (slug in) test may be conducted on wells where the static water level is above the screened, perforated or open-hole section of the well;

2) A falling head test is not applicable in cases where the static water level is below the top of the screened, perforated or open-hole interval;

3) High conductivity aquifers may not provide useful results because water levels may equilibrate before sufficient data points can be collected, in such cases electronic data-logging devices may be necessary to record sufficient data points for the slug test analysis;

4) The water level collection intervals listed for pumping tests in Pumping test description (see above) may also be used for slug test data, the sampling interval for the first few minutes should be more frequent if water level recovery is rapid;

5) The amount of initial water level change required to conduct an adequate slug test depends on the aquifer's hydraulic conductivity, a foot may be sufficient for low conductivity aquifers. High conductivity aquifers may require several feet of initial water level change to allow for sufficient data points before water levels equilibrate to static conditions;

6) Static water levels shall be measured prior to the test; and

7) The recommended analysis methods are the Bouwer-Rice method (Bouwer and Rice, 1976; Bouwer, 1989) and the Hvorslev method (Hvorslev, 1951); the Hvorslev equation is not designed to be used when the water level drops below the top of the screened, perforated or open-hole interval of the well.

4) Unacceptable Methods:

a) Hydraulic conductivity values based on tables from books (e.g. Freeze and Cherry, 1979; Table 2.2) or lithologic descriptions are not acceptable. Laboratory methods for determining hydraulic conductivity such as grain size analysis or permeameter tests are not typically acceptable because it is very difficult to collect an undisturbed sample that is representative of the aquifer properties.

C) Hydraulic Gradient and Groundwater Flow Direction

1) Published Data

a) Published hydraulic gradient and groundwater flow data exists for a number of sites in Montana. This data is typically acceptable for use in the nitrate sensitivity analysis unless there is more recent or site specific data, provided the data is for the shallowest groundwater.

2) 1/3 Regional Topographic Slope

a) A simple method to conservatively determine the ground-water hydraulic gradient is based on the principle that the hydraulic gradient is typically a subdued expression of the topographic slope. Using this assumption, the ground-water gradient can be estimated as one-third of the regional topographic slope. The regional topographic slope can be determined from a USGS topographic map in most cases. Minor topographic fluctuations, which are typically not reflected in the ground-water table, shall not be used to determine the hydraulic gradient.

b) Actual hydraulic gradients typically range from one-third to equal to the regional topographic slope. Assuming hydraulic gradient is one-third of the topographic slope, therefore, provides a conservative estimate for use in the nitrate analysis.

c) Using this method, the maximum hydraulic gradient accepted is 0.05 ft/ft (or 5 percent gradient). When no data are available and the site is in a topographically flat area, the minimum hydraulic gradient to be used in the nitrate calculations is 0.001 ft/ft unless sufficient data, such as measured water elevations as described below, are presented to support a lower hydraulic gradient.

3) Surveyed, Measured Wells (Attachment K-3, Three Point Solution Worksheet)

a) The most accurate method to determine the hydraulic gradient is to measure the static water elevation in a minimum of three wells to define the plane of the ground-water table. The following criterion shall be followed when determining the hydraulic gradient:

i) Three or more wells that define a plane (i.e. are not orientated in a straight line from a map view) should be used;

ii) Each well shall be completed in the same groundwater that is the shallowest groundwater beneath the proposed development (the wells do not have to be located in the development itself) and a well log must be submitted for each well;

iii) The elevation of the measuring point of each well (usually the top of casing) shall be surveyed to the nearest 0.1 foot (or 0.01 foot if such accuracy is needed to define the hydraulic gradient), and the well locations should be surveyed;

iv) Static (non-pumping influenced) water levels shall be measured to the nearest 0.1 foot (or 0.01 foot if such accuracy is needed to define the hydraulic gradient);

v) All water levels should be measured on the same date to minimize weather, irrigation and other external factors from disturbing the relative water elevations (in most cases, water levels collected a few days apart will also be acceptable); and

vi) Locate the wells on a USGS topographic map, construct a potentiometric map using the measured water values, and calculate a ground-water hydraulic gradient and flow direction.

D) Background Nitrate Concentration (Attachment K-4: Allowable Nitrate Levels)

1) The background nitrate concentration is used to determine the initial quality of the ground water that will be impacted by the proposed on-site sewage treatment systems. The nitrate sample(s) shall be collected according to the following procedures.

2) The well(s) used for the background nitrate sample shall be completed in the shallowest ground water. In some areas of high development or environmentally sensitive areas, EHS may require that the nitrate sample be collected from a well that is only screened in the upper 15 feet of the shallowest ground water. As nitrate enters the water table, it tends to remain near the top of the water table. If a nitrate sample is collected from a well that is completed at depth in the aquifer, it may not account for the higher nitrate concentrations near the water table and would therefore underestimate the cumulative impacts to the ground water. Ground-water samples collected from the upper several feet of the aquifer (shallow ground-water monitoring points, for example) are not acceptable because nitrate concentrations in the upper several feet of the ground water may be depressed due to dilution from precipitation or irrigation.

3) Groundwater Sampling Procedures

a) One to three well volumes shall be purged prior to collecting the ground-water sample. Note: EHS recommends three volumes be purged for greater accuracy. The sample should be collected in a laboratory-provided, unused, sample container. If the well draws dry during purging, purging is complete and the sample can be collected when sufficient water is available. The well volume (in gallons) can be calculated using the following equation:

$$volume = (pi)(r^2)(l)(7.48)$$

where:

pi = 3.14

r = radius of well (ft)

l = depth of static water column in the well (ft)

7.48 = conversion factor from ft^3 to gallons

4) An alternative method to determine when purging is complete is to measure the water temperature at five minute intervals, when three consecutive readings are within 0.5°C (12.2°, 12.5° and 12.0°, for example) the temperature is considered stable.

5) Sample collection shall be conducted prior to any water treatment system (treatment systems include but are not limited to reverse osmosis, water softeners, and distillers). The sample shall be preserved according to the procedures required by the laboratory, and transported and analyzed within the proper holding times. Concentrations shall be reported in units of nitrate as nitrogen.

6) The ground-water sample(s) should have been collected within 6 months of the date the non-significance application is initially received by EHS. A well log from the well used to collect the nitrate sample shall be included, and the well location should be marked on a topographical map or lot layout.

7) The MBMG GWIC database (See Hydraulic Conductivity Section) contains results of ground-water nitrate analyses that may be useful.

8) In general, the optimum locations for a background nitrate sample in order of <u>decreasing</u> desirability are listed below:

   a) On-site;

   b) Directly upgradient and adjacent to the proposed development;

   c) Directly downgradient and adjacent to the proposed development;

   d) Upgradient but not adjacent to the proposed development;

   e) Directly crossgradient and adjacent to the proposed development;

   f) Downgradient but not adjacent to the proposed development; and

   g) Crossgradient but not adjacent to the proposed development;

9) Because each site is unique, the above list may not be appropriate for every site depending on site-specific conditions and surrounding land use. The location of existing development in relation to the proposed development is important in selecting the best location for the background sample.

10) Typically, water samples from springs are not acceptable, but in some situations they may be acceptable sampling locations if the water is representative of the shallow ground-water quality beneath the site.

11) In most cases, a single background nitrate sample will be sufficient. However, EHS may require additional samples if EHS has reason to believe that elevated nitrate levels exist in the ground water. When multiple analyses are required, the average or median of the results may be used unless the concentrations between wells vary significantly and the average or median would not be protective of state water. Examples of situations where additional nitrate samples may be required include but are not limited to: the initial nitrate-nitrogen background sample is above 2.0 mg/L; EHS has information indicating that nearby well(s) have nitrate-nitrogen concentrations above 2.0 mg/L; the area around the proposed development is experiencing high development rates; the proposed development is in an environmentally sensitive area such as near a stream, lake or wetlands; or the potential for contamination of wells is high due to shallow water conditions and/or potable water wells are completed in a shallow unconfined aquifer.

E) Other Parameters

1) Nitrate-Nitrogen Concentration in Precipitation

   a) A default nitrate-nitrogen concentration of 1 mg/L is used for this variable. A site specific value can be substituted by measuring nitrate concentration of local precipitation. A substitute value shall consist of the average of 4 precipitation samples collected at 3-month intervals over a one-year period to account for seasonal variation. The model is relatively insensitive to changes in this parameter for most circumstances. Samples should be analyzed for nitrate, nitrite and ammonia (as nitrogen), the sum of these three parameters will be used to determine the nitrate concentration.

2) Recharge Percentage

a) Recharge percentage is the percentage of total precipitation that actually enters the ground-water system. It is a fraction of the total precipitation that lands on the ground. A default value of 20% (or 0.2) is assumed in the model, 10% (0.1) is assumed for steeper slopes.

b) Site specific data to alter the default values may be submitted for EHS review. However, the model is relatively insensitive to changes in this parameter.

3) Nitrogen Concentration in Drainfield Effluent (Attachment K-5, Nitrate Effluent Concentrations)

a) The default value for effluent nitrogen concentration from the drainfield is 50 mg/L**.** 50 mg/L is based on an average domestic strength of 60 mg/L and a 10 mg/L reduction to account for treatment in the septic tank and the drainfield. The 60 mg/L influent concentration is consistent with the range of total nitrogen concentrations in residential wastewater (EPA, 1980).

b) Although commercial waste effluent strength may vary depending on the commercial use, the domestic effluent average of 50 mg/L is maintained due to difficulty in calculating true waste strength prior to actual drainfield operation. In addition, the property use for a commercial drainfield may change several times over the drainfields life, and the average concentration (50 mg/L) is likely a good approximation over time.

c) The concentration of nitrogen in the effluent can be decreased by using denitrifying treatment systems. A list of the various alternative systems accepted by EHS and the corresponding nitrate effluent concentrations is included in Attachment K-5. Other systems, which are classified as level II systems, use a nitrate-nitrogen effluent concentration of 24 mg/L. Pursuant to ARM 17.30.715(1)(d)(iii) septic systems that treat domestic effluent using a level II system, can raise the nitrate-nitrogen concentration in ground water up to 7.5 mg/L at the end of the mixing zone. Other treatment systems must maintain nitrate-nitrogen below 5 mg/L at the end of the mixing zone, except for situations when existing ground-water nitrate-nitrogen concentrations are elevated between 5 and 7.5 mg/L due to sources other than human waste. In that situation, conventional septic systems treating domestic sewage must maintain nitrate-nitrogen below 7.5 mg/L at the end of the mixing zone.

d) Denitrification in the soils beneath the drainfield does occur, but the amount of denitrification is dependent on several soil properties and is site specific. Appropriate site-specific data shall be submitted for EHS review if an application includes denitrification factors in the nitrate analysis.

4) Quantity of Effluent

a) The approximate average single family home produces 200 gallons per day (gpd) of wastewater. In comparison, the engineering design flow for a 3 bedroom single family home wastewater treatment system is 300 gpd, but this is a maximum design flow for a single day. The 200 gpd value is based on a long-term average of typical domestic flows and is applied equally to all single family homes. A lower flow rate is not granted to smaller homes such as trailer homes and conversely a larger 4 or 5-bedroom home is not required to use a higher effluent rate in the calculations (this convention is different than the requirements in Circular DEQ 4 and local septic system regulations, which uses the number of bedrooms to determine the lineal footage of each drainfield).

b) Typical flows for commercial establishments can be estimated from information in Circular DEQ 4 or local septic system regulations. The average design flow of the commercial drainfield should be divided by 200 gpd to get the single family home equivalents for use in the Nitrate Sensitivity Analysis and Phosphorous Breakthrough calculation.

F) Mixing Zones (Attachment K-6, Mixing Zone Drawing)

1) Mixing zones are required for both primary and replacement drainfields.

2) Mixing Zone Thickness

a) The standard mixing zone thickness is 16.4 feet. This value is applicable for most circumstances since most ground-water bearing zones are greater than 16.4 feet thick. However, when evidence exists that the shallow ground-water zone is less than 16. Four (4) feet thick (for example, a gravel aquifer that is underlain by a low permeability clay at 5 feet below the water table), the mixing zone thickness shall equal the saturated ground-water thickness above the lower permeability unit (5 feet in this example)

3) Mixing Zone Length

a) Standard ground-water mixing zone lengths are prescribed in ARM 17.30.517(1)(viii) and are summarized below (Table K-2).

Table 2
Summary Table
(Not part of rule, read rule (ARM 17.30.716) for specifics)

Type of System	Lot size (acres)	Property size (acres)	Mixing zone length (feet)
Single family	< 2	N/A	100
Single family	> 2	5 to 10	200
Single family	> 2	< 5.0; > 10.0	500
Commercial	N/A	N/A	500
Public	N/A	N/A	500
Duplex	N/A	N/A	500
Multiple-family	N/A	N/A	500

b) If the parameters used to define a standard mixing zone (ARM 17.30.517 and 17.30.516 for groundwater and surface water mixing zones respectively) are not applicable or desired by the applicant, a Source Specific Mixing Zone (SSMZ) may be requested as per ARM 17.30.518. The information requirements listed in ARM 17.30.518 apply primarily when a longer than standard mixing zone is requested. Shorter than standard mixing zones do not typically require the additional information required in ARM 17.30.518, but may be required by EHS.

c) The most common request for a SSMZ is to shorten the standard mixing zone length. Most of these requests are approved and will continue to be approved without additional information as long as the shorter mixing zone does not threaten the quality of existing or potential water supplies. The second most common request is to lengthen the standard mixing zone to meet the nondegradation nitrate standard. Other requests for SSMZs include modifying any of the parameters defined for a standard mixing zone in ARM 17.30.517(1)(d). As a general "rule of thumb" EHS will require, at a minimum, the following additional information to review an application for a SSMZ for domestic sewage treatment systems.

i) Install three on-site monitoring wells to be completed in the shallowest groundwater beneath the site.

ii) The three wells should be used to determine the hydraulic gradient beneath the site. The wells should be surveyed and the water elevations measured (to the nearest 0.01 foot) on two separate dates at least two weeks apart.

iii) A long term (at least 24 hours long, with corresponding recovery data) pumping test should be conducted on one of the three monitoring wells to determine the hydraulic conductivity of the shallow groundwater beneath the site (observation wells may be used). The test(s) should be conducted according to the section on Pumping and Slug Tests.

iv) Groundwater from each well should be collected and analyzed for nitrate (as nitrogen) concentration for use in determining the background nitrate concentration.

v) Compliance monitoring may be required.

vi) A contingency plan may be necessary if pollutants migrate beyond the mixing zone at concentrations above the allowable limit.

vii) A specific explanation as to why the proposed mixing zone is the smallest practicable size and why it will have a minimum practicable effect on water users.

d) As stated above, EHS cannot require additional treatment for a SSMZ. However, in some cases (as determined on a site-by-site basis), EHS may remove some or all of the above requirements if the applicant proposes additional treatment, such as level II treatment.

e) If a state surface water lies within the ground-water mixing zone, the mixing zone ends at the edge of the mean high-water level in the surface water. If the appropriate nitrate levels cannot be met within the shortened ground-water mixing zone, the sewage treatment system should be moved, revised or a surface water mixing zone (per ARM 17.30.516) should be applied for. Standard mixing zones in lakes or wetlands for new or increased sources are not permitted per ARM 17.30.516(2), however standard mixing zones are allowed for streams, rivers, etc.

f) The accurate dimensions of each mixing zone (primary and replacement) shall be shown on a map along with any nearby wells as discussed in Site Plan Requirements.

4) Mixing Zone Width

a) The mixing zone width is determined by the total width of the primary drainfield as measured perpendicular to the ground-water flow direction. The width increases downgradient from the drainfield according to the equation listed in ARM 17.30.517(1)(d)(iii)(B) which states, *"...equal to the width of the source plus the distance determined by the tangent of* 5^0 *times the length of the mixing zone on both sides of the source."*

G) Cumulative Effects (Attachment K-7, Cumulative Effects Example)

1) In many instances, multiple drainfields will be aligned in the direction of ground-water flow, which will create a cumulative nitrate impact on the shallow ground water. Cumulative impacts between two or more drainfields on the same development must be accounted for. In addition, cumulative impacts between the proposed development and previously approved/existing surrounding developments must be accounted for if the background nitrate sample(s) do not adequately account for the surrounding development.

2) If any part of two drainfield mixing zones overlap, as measured in the direction of ground-water flow, cumulative impacts must be assessed (note: the 5° dispersion widening is not accounted for when determining overlap of drainfields). An example of when multiple drainfields overlap is included in Attachment K-7. The Bauman-Schafer model should be used to account for cumulative effects according to the procedures outlined in Attachment K-7.

H) Confinement

1) If the shallowest groundwater is confined then nitrate cannot affect that groundwater. Therefore the impact of nitrate to the groundwater is nonsignificant. If this determination is made then phosphorous breakthrough still needs to be determined nonsignificant in order to complete nondegradation analysis.

2) Typically EHS requires a number of well logs that all show a confining layer such as clay in excess of 20 feet thick in the area surrounding all sides of the proposed development. The amount of evidence depends on site-specific characteristics. The applicant may be required or may desire in some cases to conduct a pumping test with an observation well to determine aquifer storativity. In conjunction with supporting lithologic data, storativity values between 0.001 and 0.00001 are acceptable for determining confined conditions, depending on the aquifer properties. Values lower than 0.00001 are unrealistic values for any aquifer therefore indicate problems with the pumping test.

I) Class III or IV Waters

1) The nitrate-nitrogen standards at the end of the mixing zone (ARM 17.30.715(1)(d)) apply to high quality ground water (75-5-103(9), MCA). If the shallowest ground water is not a high quality water, the nitrate standards in ARM 17.30.715(1)(d) are not applicable at the end of the mixing zone. However, the human health standard for nitrate (10 mg/L as listed in Department Circular WQB-7) is applicable at the end of the mixing zone.

2) A high quality ground water is defined in 75-5-103(10), MCA, as a class I or II ground water. Class III and IV ground waters are not high quality waters. The ground-water classification system is presented in the Montana Ground Water Pollution Control System Rules (17.30.1006 et seq.). The information needed to classify the ground water for any particular area will be determined on a case-by-case basis. This information will in most cases require multiple ground-water analyses for specific conductance. Alternatively, a report published by or for a state or federal agency that determines the specific conductance of shallow water quality in and around the proposed development may be considered in classifying the local ground-water quality.

3) In addition, the Montana Ground Water Pollution Control System Rules (17.30.1006), include other modifications of the nitrate human health standard when the ground water quality is very poor (specific conductance over 7,000 umhos/cm), or when class III or IV ground water has very low hydraulic conductivity (less than 0.1 feet/day). Refer to ARM 17.30.1006 for complete details.

III Phosphorous Breakthrough

A) Dispersion angle in phosphorous plume (Attachment K-8, Phosphorous Breakthrough Calculation Sheet)

1) The dispersion angle of 5° that is used in the nitrate sensitivity analysis is also appropriate for use in the calculation of phosphorous breakthrough as determined by MDEQ in April, 2000. This dispersion angle has been include in the revised phosphorous breakthrough calculation sheet (Attachment K-8).

B) Distance to Surface Water

1) A state surface water is defined in the Water Quality Act (75-5-103(9)(25), MCA). If a surface water does not meet the definition of a “state water” or “high quality state water”,

the phosphorous analysis does not apply to phosphorous discharge to that particular water. In such cases, the phosphorous analysis will have to be calculated for the next downgradient surface water that is classified as a “high quality state water”. A surface water feature is not “high quality state water” if the surface water flows for less than 90 days in a typical year or the surface water is an irrigation canal that does not return to state waters.

2) If site-specific data are not presented to determine the ground-water flow direction (for example, when the ground-water flow directions is assumed from the local land topography), the ground water is assumed to move along the shortest distance between the drainfield and the water body. Otherwise, the distance to the nearest state water is measured parallel to the measured ground-water flow direction.

C) Mixing Depth and Plume Thickness

1) The most common method to determine a minimum depth to a limiting layer or ground water is to use the on-site test pit information. If ground-water monitoring through the high water period or the soil descriptions in the test pit indicate the depth to the water table, that minimum depth (minus the final burial depth of the drainfield laterals, which is typically two feet) is used in the calculation. If no evidence of ground water is identified and there is no limiting layer, then the bottom of the test pit (minus the final burial depth of the drainfield laterals) is used in the calculations. If a restrictive layer such as clay or low permeability bedrock is noted in the test pit description, the depth of the restrictive layer (minus the final burial depth of the drainfield laterals) is used in the calculation.

2) Static water levels in well logs are not typically acceptable because well logs do not typically note the first water and water levels measured after drilling may not be indicative of true static water levels, particularly in lower permeability materials. However, if an on-site well log is located in a shallow, unconfined, high conductivity aquifer (that does not have restrictive layers) and static water level data are available during the local high water table period (usually spring or summer depending if the ground-water levels are affected more by spring runoff or summer irrigation), that data may be used in conjunction with the test pit information. If no evidence of ground water or limiting layer was found in the test pit, the well(s) information may be used to show that static water levels are below the bottom of the test pit.

3) If the ground water cannot physically enter the surface water that surface water cannot be affected by the phosphorous and a breakthrough calculation to that surface water does not need to be conducted. For example, if the elevation of the bottom of an irrigation ditch is higher than the drainfield, the phosphorous cannot enter the ditch at that point (note that at some point downgradient of the site the ditch may be below the drainfield and the phosphorous calculations may need to be run to that point).

4) Plume Thickness: this value is defined as either 0.5 feet for coarse-textured soils or 1.0 foot for fine-textured soils. Fine-textured soils are defined as containing 35% or more of silts and/or clay material (a sandy loam or finer) as determined by test pits. Typically, sieve analysis do not have to be conducted to determine the soil classification; the primary descriptor of the soil type (i.e. clay, sand, etc.) is used to determine whether the soil is defined as coarse or fine grained. The soil texture is determined at the top of the high water level or restrictive layer, or where the high water level/restrictive layer is assumed to be (e.g. the bottom of a dry test pit).

D) Measuring Drainfields

1) Drainfield Length (as measured perpendicular to groundwater flow)

a) This dimension is used to determine the width of the soil available to adsorb phosphorous from the drainfield to the surface water. In most cases, the length is equal to the long axis of the drainfield. However, there are cases where the drainfield may be skewed in relation to ground-water flow or the long axis may be parallel to ground-water flow. The calculations can be completed for any drainfield orientation, but the 50-year breakthrough limit is easier to satisfy when the long axis of the drainfield is perpendicular or nearly perpendicular to the ground-water flow direction.

2) Drainfield Length and Width

a) These dimensions are used to determine the area of soil directly beneath the drainfield that is available to adsorb phosphorous.

b) An additional 2 feet can be added to each of the outside laterals to account for lateral dispersion of the effluent when calculating the drainfield width. For example, if the drainfield consists of 3 laterals on 7-foot centers, the width in the calculations is equal to: 7' + 7' + 2' + 2' = 18 feet.

c) The length and width for a mound system is calculated using the same method as described in this section and below in the Drainfield Lateral Spacing section. The area is not based on the basal area of the sand mound.

3) Drainfield Lateral Spacing

a) For purposes of calculating the drainfield area, the maximum allowable distance between drainfield laterals is 10 feet. For example, if there are 2 laterals spaced on 14 foot centers, only 10 feet of that separation can be used in calculating the amount of soil available for phosphorus absorption beneath the drainfield.

E) Phosphorous Concentration

1) The default value for effluent phosphorus concentration from the drainfield is 10.6 mg/L. 10.6 mg/L is equivalent to 6.44 lbs/year (lbs/year are the units used in the phosphorous calculation sheet) for a single family home that produces 200 gallons per day on average. This concentration is used as an average value for domestic and commercial effluent.

2) Although commercial waste effluent strength may vary depending on the commercial use, the average of 10.6 mg/L (or 6.44 lb/yr per 200 gpd) is maintained due to difficulty in calculating true waste strength prior to actual drainfield operation. In addition, the property use for a commercial lot may change several times over the life of a drainfield, and the average concentration (10.6 mg/L) is likely a fair approximation over time.

F) Soil Phosphorus Adsorption Capacity

1) The default value for the soils ability to adsorb phosphorus is 200 ppm. The actual adsorption capacity of a soil can be measured via laboratory methods. The value of 200 ppm should be used unless adequate information is submitted regarding the site-specific adsorption capacity of the soils beneath the drainfield.

2) Typically, finer grained sediments (clay, silt) contain more adsorption capacity than sands. The laboratory analysis removes all gravel or larger sized particles from the sample before conducting the test, which affects the bulk adsorption capacity of any soil which contains gravel or larger sized grains.

3) The location and number of samples that should be collected are site-specific depending on the local variability of soils, the type/size of treatment system and other site variables. Contact EHS to determine the appropriate quantity and location of samples for a particular site.

G) Cumulative Effects for Phosphorous (Attachment K-9)

1) In many instances multiple drainfields will be aligned in the direction of ground-water flow, which will create a cumulative phosphorus impact on the surface water. Cumulative impacts between two or more drainfields on the same development must be accounted for. In addition, cumulative impacts between the proposed development and previously approved/existing surrounding developments must be accounted for.

2) If any part of two drainfields overlap, as measured in the direction of ground-water flow, cumulative impacts must be assessed. For example, to determine the cumulative effects for two drainfields, the phosphorus equation should be completed using the distance from the upgradient drainfield to the second downgradient drainfield as the "distance from drainfield to surface water" in the equation. If the breakthrough is greater than 50 years, then their is no cumulative effect and the phosphorus equation should be run as usual on the downgradient drainfield. However, if the breakthrough from the first to second drainfield is less than 50 years, the calculations for the downgradient drainfield should account for the cumulative effects. For example, if the breakthrough from the upgradient to downgradient drainfield is 35 years, then the breakthrough for the downgradient drainfield must account for the additional 15 years (50 minus 15 years). Therefore, the breakthrough for the downgradient drainfield must be at least 65 years (50 plus 15 years) to the surface water to be nonsignificant degradation of state waters (See Attachment K-9 for a detailed explanation of cumulative effects calculation for phosphorous breakthrough).

IV Categorical Exemptions

A) The nondegradation rules include a section exempting certain sewage treatment systems from meeting the nitrate and phosphorus criteria (ARM 17.30.716). The exemptions only apply to individual sewage treatment systems that serve a single domestic living unit and the lot is not within a major subdivision. The exemptions have six criteria and <u>ALL six criteria must be met</u> in order for the system to qualify for categorical exemption. The following summary describes the information needed to satisfy each criteria. Attachment K-10 is a summary table for simplified reading of this rule.

B) Lot Size

1) Exemptions include 4 sets of criteria for different lot sizes (> 1 acre, > 2 acres, >5 acres, and >20 acres)

C) Depth to Uppermost Aquifer or Fractured Bedrock

1) Most bedrock located near the earth's surface is fractured to some degree. Without adequate information that a specific bedrock layer is not fractured, bedrock will be considered to be fractured for the purposes of the categorical exemptions.

2) The depth to bedrock can be shown by a minimum of three on-site or nearby well logs that indicate there are no bedrock units above the minimum distance required or other adequate information such as published reports. EHS may require additional local well logs, geologic reports or test pits to verify the absence/existence of shallow bedrock units.

3) The depth to the uppermost aquifer can be shown by a minimum of three on-site or nearby well logs that indicate there are no potentially water bearing units above the minimum distances prescribed in ARM 17.30.716(vii). Other sources of information such as published reports may be used to demonstrate depth to an aquifer. EHS may require additional local well logs, hydrogeologic reports or test pits to verify the depth to the uppermost aquifer. Aquifer is defined for the purposes of this rule in ARM 17.30.716(2)(a).

D) Ground Water Nitrate (as Nitrogen) Concentration

1) See Nitrate Sensitivity Analysis section regarding background nitrate (as nitrogen) samples.

2) Except for lots over 20 acres, if information indicates any well within a 1/4 mile radius of the proposed development contains nitrate-nitrogen over 2.0 mg/L, the categorical exemptions will not be applicable. This is not to require that each well within a 1/4 mile radius be sampled by the applicant, but if EHS is aware of information regarding elevated nitrate concentrations, it may be used to reject the applicability of a categorical exemption.

E) Soil Type

1) The soil type shall be determined by a test pit (at least eight feet deep) in or in the immediate vicinity of each and every proposed drainfield location and described by a person qualified in soil sciences. Local soil classification maps and descriptions should also be included. The soil description must include the upper eight feet of the soil profile.

F) Percolation Test

1) Percolation tests must be conducted in each and every proposed drainfield location. The measured percolation rate for each drainfield that is proposed for the categorical exemption must be greater (i.e. slower) than the prescribed rate.

2) For example, ARM 17.30.716(vii) requires that the percolation rate must be greater than 10 minutes/inch for lots greater than five acres. In this example a percolation rate of 15 minutes/inch would meet this requirement of the categorical exemption, but a rate of 7 minutes/inch would not, and the site would not qualify for a categorical exemption.

G) Distance to State Water

1) The distance from the drainfield to any state surface water must be greater than 300 feet as measured parallel to the ground water flow direction. In addition, the long dimension of the drainfield must be perpendicular to the direction of ground water flow.

V Adjacent to Surface Waters

A) Developments that are located adjacent to state waters will require an analysis of the effects for the proposed drainfield systems on the nearest downgradient surface water's quality. Nitrate values in the surface water can not exceed the trigger value as set forth in WQB 7 of 0.01mg/L (as per ARM 17.30.715 (1)(c)). If the proposed development exceeds that trigger value then the applicant must demonstrate that the increase in nitrate in that surface water will not cause an impact based on the narrative standards in ARM 17.30.715(1)(g).

B) Determination of whether a specific development is considered adjacent to state waters is site specific and depends upon the geology, size of system and other site properties.

C) Lakes and Ponds

1) The dilution value for trigger levels (0.01 mg/L) in lakes and ponds is calculated using Attachment K-11, Dilution Equation. This equation requires that the flow rate into or out of the water body be known. This can be determined from a stream gauge on a stream flowing into or out of the lake or by groundwater flow. The use of groundwater flow is the most common because it requires the least amount of data. Attachment K-12 demonstrates how to use Darcy's Law (Q=KIA) to determine the groundwater flow. The calculation of trigger values is sensitive to the nitrate concentration in the effluent. Therefore systems that use level II treatment will have lower impacts.

D) Streams and Rivers

1) The same Dilution equation is used to calculate dilution values for streams and rivers. The flow rate of the water body is determined by stream gauging to determine the 7Q10 flow of that stream where the effluent is entering it. The 7Q10 flow is the 7 day, 10 year low flow for the impacted section of stream.

NONDEGRADATION ATTACHMENT #1

NITRATE SENSITIVITY ANALYSIS SPREADSHEET

Model Updated 02/98

SITE NAME: ______________________
COUNTY: ______________________
LOT #: ______________________
NOTES: ______________________

VARIABLES	DESCRIPTION	VALUE	UNITS
K	Hydraulic Conductivity		ft/day
I	Hydraulic Gradient		ft/ft
D	Depth of Aquifer (usually constant)	16.4	ft
L	Mixing Zone Length (see ARM 17.30.517(1)(d)(viii)		ft
Y	Width of Drainfield Perpendicular to Ground Water Flow		ft
Ng	Background Nitrate (as Nitrogen)		mg/L
Nr	Nitrate (as Nitrogen) in Precipitation (usually constant)	1.0	mg/L
Ne	Nitrates in Effluent (50 for conventional; 24 for level II)	50	mg/L
#l	Number of Single Family Homes on the Drainfield	1.0	
Ql	Quantity of Effluent per Single Family Home (constant)	26.70	ft3/day
P	Precipitation		in/year
V	% Precipitation Recharging Ground Water (usually constant)	0.20	

EQUATIONS

W	Width of Mixing Zone Perpendicular to Ground Water Flow = (0.175)(L)+(Y)		ft
Am	Cross Sectional Area of Aquifer Mixing Zone = (D)(W)		ft2
As	Surface Area of Mixing Zone = (L)(W)		ft2
Qg	Ground Water Flow Rate = (K)(I)(Am)		ft3/day
Qr	Recharge Flow Rate = (As)(P/12/365)(V)		ft3/day
Qe	Effluent Flow Rate = (#l)(Ql)	26.70	ft3/day

SOLUTION

Nt	**Nitrate- N Concentration at End of Mixing Zone =((Ng)(Qg)+(Nr)(Qr)+(Ne)(Qe)) / ((Qg)+(Qr)+(Qe))**		**mg/L**

BY:
DATE:

NONDEGRADATION ATTACHMENT #2

MODIFIED COOPER-JACOBS EQUATION

HOW TO CALCULATE HYDRAULIC CONDUCTIVITY FROM PUMPING TEST DATA ON A DRILLERS LOG

EQUATION #1:

$$T = [(Q/s)(1500) / 7.48$$

Where:

T	=	transmissivity (square feet/day)
Q	=	pumping rate (gpm)
S	=	drawdown (feet) *{this is the difference between static water level and pumping water level}.*
1500	=	factor used for unconfined aquifer; value should be 2000 for a confined aquifer.
7.48	=	conversion factor – gallons to ft^3

EQUATION #2:

$$K = T/b$$

Where:

K = hydraulic conductivity (feet/day)

T = transmissivity (square feet/day)

B = aquifer thickness (feet). *{Aquifer thickness is dependent on whether the well is completed with: 1) a perforated casing or screen, 2) an open bottom (also known as an open casing), or 3) an open hole. An open bottom well is completed by extending the well casing to the bottom of the borehole with no casing perforations, all water enters through the bottom of the casing. An open hole well is completed by continuing to drill a borehole beyond the bottom of the casing, this type of well is typically drilled into bedrock which allows the borehole to remain open without a casing. The aquifer thickness used for each type of well is listed as follows:*

WELL COMPLETION TYPE:	*AQUIFER THICKNESS (b)*
Perforated or screened	*Perforation/screen thickness*
Open bottom	*10 feet*
Open hole	Open hole interval (i.e. distance between bottom of casing and bottom of borehole)

NONDEGRADATION ATTACHMENT #3

GROUNDWATER GRADIENT & FLOW DIRECTION CALCULATIONS
THREE POINT SOLUTION WORKSHEET

Instructions to determine groundwater (GW) gradient and flow direction based on Static Water Elevations (SWE) of three wells.

A. (BASE DATA) Record elevation difference and horizontal distances (HD) between wells:

Well	**Topo Elevation**		**Static Water Level**		**Static Water Elevations**	**Wells**		**Horizontal Distance**
#1		**-**		**=**		**#1 to #2**	**=**	
#2		**-**		**=**		**#2 to #3**	**=**	
#3		**-**		**=**		**#3 to #1**	**=**	

B. Plot the well locations on a scaled diagram:

Proposal Name:____ Scale: ___″ = ____′

C. Perform the following calculations:

1. Record the Intermediate Static Water Elevation (ISWE) _________
2. Calculate the position between the High Static Water Elevation (HSWE) well and the Low (LSWE) well where the SWE is the same as the intermediate well:

   Step (a): HSWE=________ minus LSWE__________ = (a)________
   Step (b): Horizontal distance between HSWE well and LSWE well = _______feet ÷ (a)_______ = (b) ________
   Step (c): HSWE _______ minus ISWE _____ = (c) ________
   Step (d): (b) _______ X (c) ________ = (d) _________ = the horizontal distance between the HSWE well and LSWE well that is equal to the ISWE.

3. Measure the distance (d) from the HSWE well along the line between it and the LSWE well, and plot that position on the diagram.
4. Draw a straight line from the ISWE well to position (d) on the well location diagram. This represents the water level contour line along which the SWE is the same as the ISWE well.
5. Draw a line perpendicular to the ISWE contour line through the HSWE well location on the well location diagram. This is the groundwater flow direction (high to low). The distance along this groundwater flow line from the HSWE well to the ISWE contour line is (e).

D. Calculate the Hydraulic Gradient (HG) of the groundwater by dividing (c) above by (e) above:

(c) ________ ÷ (e) _________ **= (HG) _____________ ft/ft**

NONDEGRADATION ATTACHMENT #4

ALLOWABLE NITRATE LEVELS

Background Nitrate-N Levels (mg/L)	**Allowable Mixing Zone Concentrations of Nitrate-N in mg/L****
0 - 5.0	**5.0** (for standard septic system) **7.5** (for level II treatment systems)
5.0 – 7.5	**7.5** (nitrate is primarily from sources other than human waste; otherwise no increase above background levels) **7.5** (for level II treatment systems)
7.5 – 10.0	NO INCREASE
$\geq$ 10.0 (EPA MCL)	NO INCREASE

** If shallowest groundwater is not a high quality groundwater, allowable level is 10 mg/L. High quality water is defined as Class I or Class II waters (75-5-103, MCA). Class I or II water has a specific conductance less than 2500 µmhos/cm at 25º C (ARM 17.30.1006). Note that ARM 17.30.1006(3)(c)(i), 17.30.1006(4)(c)(ii), and 17.30.1006(5) include modified standards for groundwater that is not high quality.

NONDEGRADATION ATTACHMENT #5

NITRATE EFFLUENT CONCENTRATION GUIDELINES & LEVEL II TREATMENT

The following is a guideline for calculating the concentration of nitrate in effluent from various onsite sewage treatment systems. These values will be used as input into the models used to calculate nondegradation assessments for onsite treatment systems.

SYSTEM TYPE:	NITRATE – N (mg/L)	
φPressure Dosed, Closed Bottom, Intermittent Sand Filter	24	at bottom of drainfield trenches
Pressure Dosed, Open Bottom, Intermittent Sand Filter	36	at bottom of sand filter
φPressure Dosed, Recirculating Sand Filter	24	at bottom of drainfield trenches
Pressure Dosed, Sand Lined Trenches	50	at bottom of trenches
Gravity Fed, Sand Lined Trenches	50	at bottom of trenches
Gravity Fed, Standard Absorption Trenches	50	at bottom of trenches
φPressure Dosed, Elevated Sand Mounds	24	1 foot below base of mound
Shallow-capped DF, and Fill "Systems"	50	at bottom of trenches
φOther Experimental Systems	Conservative values as per adequate published tests	

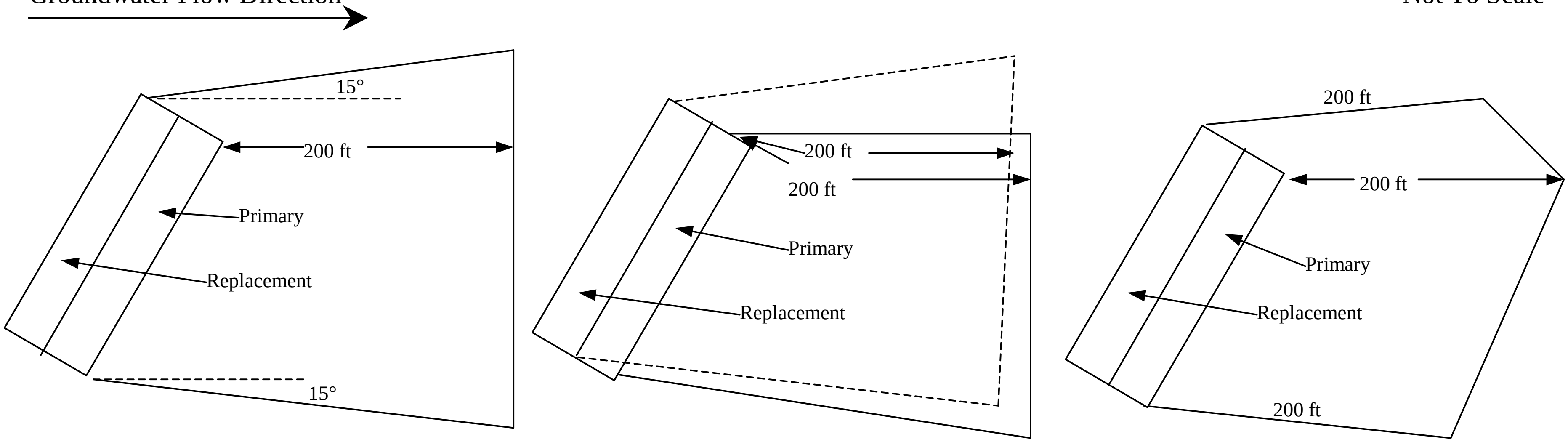
NOTE: φ = May be used to meet Level II treatment requirements.

NONDEGRADATION ATTACHMENT #6

ACCEPTED METHODS FOR DRAWING MIXING ZONES
DRAINFIELDS SKEWED TO GROUNDWATER FLOW DIRECTION

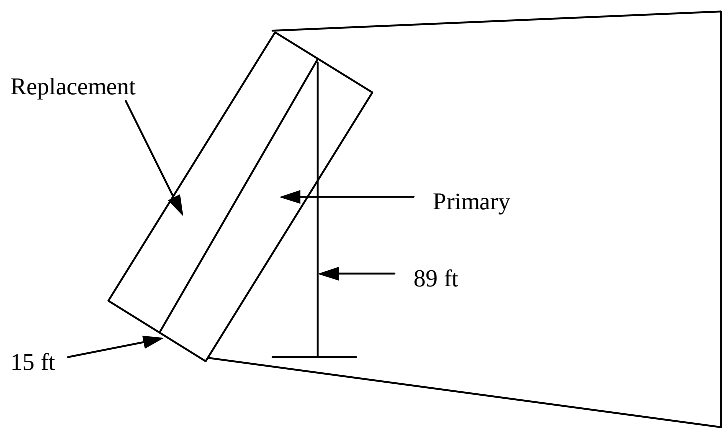
Groundwater Flow Direction

Not To Scale



Most Conservative OR OR **Most Accurate**

The method used to draw the mixing zone does not change the width of the drainfield used in the nitrate sensitivity analysis. Just the primary **OR** the replacement width perpendicular to the groundwater is used, see below



In this case the analysis is being done for the primary drainfield

NONDEGRADATION ATTACHMENT #7

CUMULATIVE IMPACTS EXAMPLES for NITRATE SENSITIVITY ANALYSIS

Please refer to the attached schematics and spreadsheets when following these examples. The background concentration for drainfield B (Scenario 1) is calculated by extending the mixing zone for drainfield A to the end of the mixing zone for drainfield B. Note that the standard mixing zone for drainfield A would not actually change, it would just be lengthened in the calculation to determine the background for drainfield B.

If there are 3 or more drainfields in a row, the method is similar (see Scenario 2), the background nitrate concentration for drainfield B is calculated by extending the drainfield A mixing zone to the end of the last downgradient mixing zone (mixing zone C). The background nitrate concentration for drainfield C is calculated by extending the drainfield B mixing zone to the end of mixing zone C.

Note that there is no change in the dilution equation, the only change is the mixing zone length to calculate the background nitrate concentration for successive drainfields. Also note that each drainfield must meet the nitrate limit at the end of its standard mixing zone (see the calculation spreadsheets for Scenario 2 – Attachments K-7a, K-7b and K –7c).

One of the complications that might arise with this method is when there are 3 or more drainfields in a row and the "worst-case" cumulative effects occurs between the upper drainfields. One example of this is when at least one of the lower (i.e. downgradient) drainfields are separated from the upper drainfields by a comparatively large distance. For example, see Scenarios 3 and 3A, if drainfields A and B are 100 feet apart and drainfield C is 1,000 feet from drainfield A, the worst case of cumulative effects would be at the drainfield B mixing zone boundary (Scenario 3A: 4.73 mg/L) rather than at the drainfield C mixing zone boundary (Scenario 3: 4.66 mg/L). This complication shouldn't happen in most situation, but it is something to be aware of.

NONDEGRADATION ATTACHMENT #7a

NITRATE SENSITIVITY ANALYSIS – Cumulative Effects examples

Model Updated 01/24/96

NOTES: SCENARIO 2: Calculating background nitrate concentration for drainfield B.

Variables	***Description***	***Value***	***Units***
K	Hydraulic Conductivity	25.00	Ft/day
I	Hydraulic Gradient	0.0100	Ft/ft
D	Depth of Aquifer (usually constant)	16.4	ft
L	Mixing Zone Length (see ARM 17.30.517 (1)(d)(viii)	800	ft
Y	Width of Drainfield Perpendicular to Ground Water Flow	100	ft
Ng	Background Nitrate (as Nitrogen)	0.00	Mg/L
Nr	Nitrate (as Nitrogen) in Precipitation (usually constant)	1.0	Mg/L
Ne	Nitrates in Effluent (50 for conventional; 24 for level II)	50.00	Mg/L
#1	Numbers of Single Family Homes on the Drainfield	1.0	
QI	Quantity of Effluent per Single Family Home (constant)	26.70	Ft3/day
P	Precipitation	12.0	In/year
V	Percent of Precipitation Recharging Ground Water (usually constant)	0.20	

Equations			
W	Width of Mixing Zone Perpendicular to Ground Water Flow = (0.175)(L)+(Y)	240.00	ft
Am	Cross Sectional Area of Aquifer Mixing Zone = (D) (W)	3936.00	Ft2
As	Surface Area of Mixing Zone = =(L) (W)	192000.00	Ft2
Qg	Ground Water Flow Rate = (K) (I) (Am)	984.00	Ft3/day
Qr	Recharge Flow Rate = (As) (P/12/365) (V)	105.21	Ft3/day
Qe	Effluent Flow Rate = (#1) (QI)	26.70	Ft3/day

Solution			
Nt	Background nitrate for drainfield B	1.29	Mg/L

NONDEGRADATION ATTACHMENT #7b

NITRATE SENSITIVITY ANALYSIS – Cumulative Effects examples

Model Updated 01/24/96

NOTES: SCENARIO 2: Calculating background nitrate concentration for drainfield C.

Variables	***Description***	***Value***	***Units***
K	Hydraulic Conductivity	25.00	Ft/day
I	Hydraulic Gradient	0.0100	Ft/ft
D	Depth of Aquifer (usually constant)	16.4	ft
L	Mixing Zone Length (see ARM 17.30.517 (1)(d)(viii)	600	ft
Y	Width of Drainfield Perpendicular to Ground Water Flow	100	ft
Ng	Background Nitrate (as Nitrogen)	1.29	Mg/L
Nr	Nitrate (as Nitrogen) in Precipitation (usually constant)	1.0	Mg/L
Ne	Nitrates in Effluent (50 for conventional; 24 for level II)	50.00	Mg/L
#1	Numbers of Single Family Homes on the Drainfield	1.0	
QI	Quantity of Effluent per Single Family Home (constant)	26.70	Ft3/day
P	Precipitation	12.0	In/year
V	Percent of Precipitation Recharging Ground Water (usually constant)	0.20	

Equations			
W	Width of Mixing Zone Perpendicular to Ground Water Flow = (0.175)(L)+(Y)	205.00	ft
Am	Cross Sectional Area of Aquifer Mixing Zone = (D) (W)	3362.00	Ft2
As	Surface Area of Mixing Zone = =(L) (W)	123000.00	Ft2
Qg	Ground Water Flow Rate = (K) (I) (Am)	840.50	Ft3/day
Qr	Recharge Flow Rate = (As) (P/12/365) (V)	67.40	Ft3/day
Qe	Effluent Flow Rate = (#1) (QI)	26.70	Ft3/day

Solution			
Nt	Background nitrate for drainfield B	2.66	Mg/L

NONDEGRADATION ATTACHMENT #7c

NITRATE SENSITIVITY ANALYSIS – Cumulative Effects examples

Model Updated 01/24/96

NOTES: SCENARIO 2: Calculating nitrate concentration at end of drainfield C mixing zone (after cumulative effects of drainfields A and B are calculated)

Variables	***Description***	***Value***	***Units***
K	Hydraulic Conductivity	25.00	Ft/day
I	Hydraulic Gradient	0.0100	Ft/ft
D	Depth of Aquifer (usually constant)	16.4	ft
L	Mixing Zone Length (see ARM 17.30.517 (1)(d)(viii)	100	ft
Y	Width of Drainfield Perpendicular to Ground Water Flow	100	ft
Ng	Background Nitrate (as Nitrogen)	2.66	Mg/L
Nr	Nitrate (as Nitrogen) in Precipitation (usually constant)	1.0	Mg/L
Ne	Nitrates in Effluent (50 for conventional; 24 for level II)	50.00	Mg/L
#1	Numbers of Single Family Homes on the Drainfield	1.0	
QI	Quantity of Effluent per Single Family Home (constant)	26.70	Ft3/day
P	Precipitation	12.0	In/year
V	Percent of Precipitation Recharging Ground Water (usually constant)	0.20	

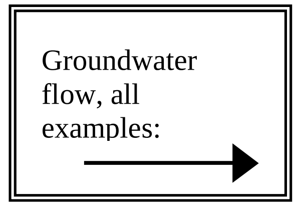
Equations			
W	Width of Mixing Zone Perpendicular to Ground Water Flow = (0.175)(L)+(Y)	117.50	ft
Am	Cross Sectional Area of Aquifer Mixing Zone = (D) (W)	1927.00	Ft2
As	Surface Area of Mixing Zone = =(L) (W)	11750.00	Ft2
Qg	Ground Water Flow Rate = (K) (I) (Am)	481.75	Ft3/day
Qr	Recharge Flow Rate = (As) (P/12/365) (V)	6.44	Ft3/day
Qe	Effluent Flow Rate = (#1) (QI)	26.70	Ft3/day

Solution			
Nt	Background nitrate for drainfield B	5.09	Mg/L

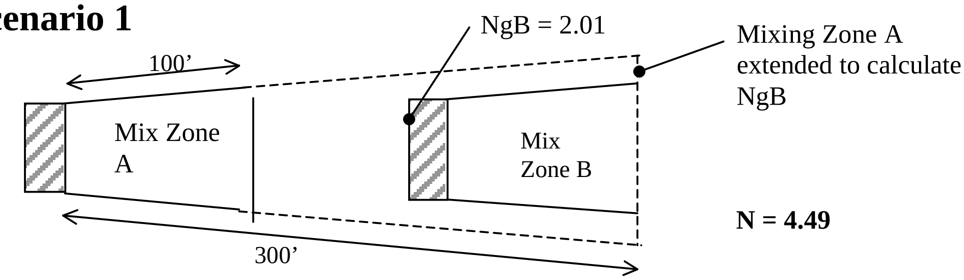
NONDEGRADATION ATTACHMENT #7d

Notes:

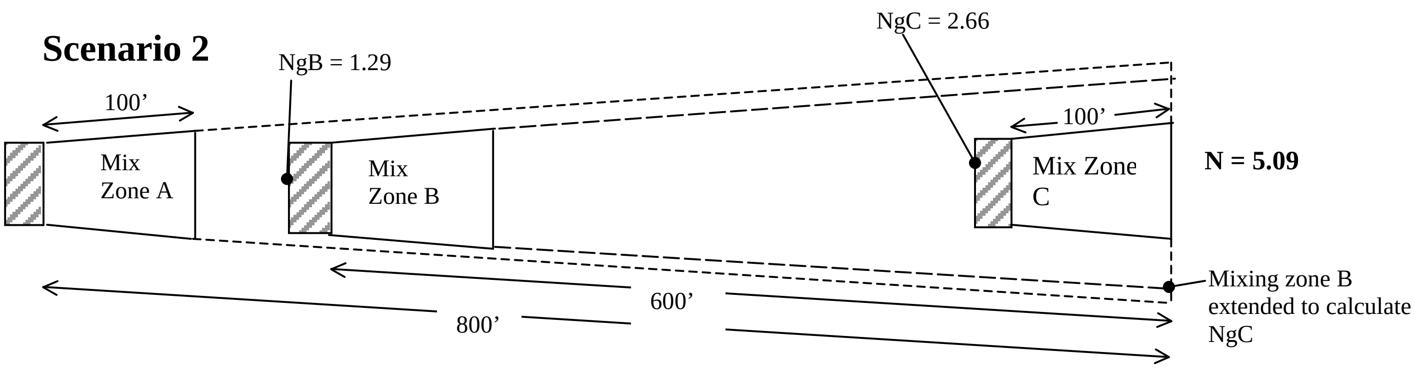
1) Drawings Not To Scale.
2) **All beginning nitrate values (NgA) are zero**.
3) NgC, NgB = background nitrate values drainfields C, B, respectively.



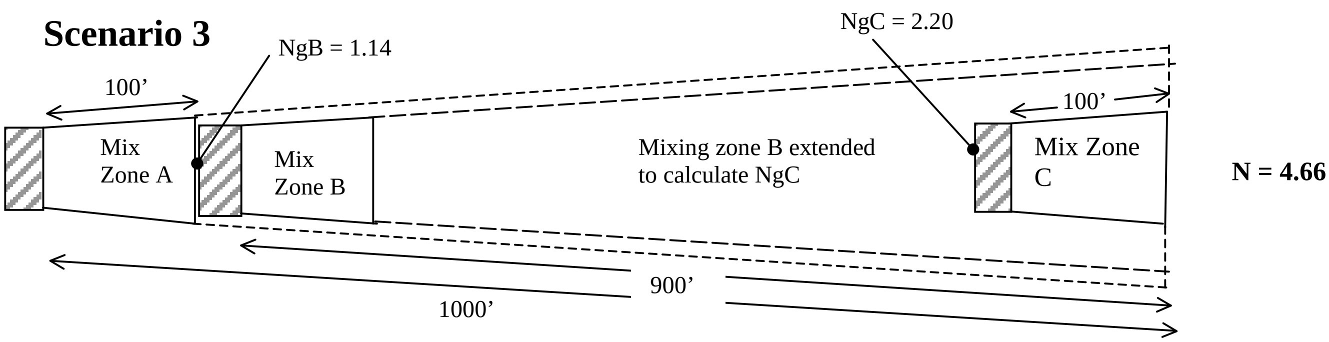
Scenario 1



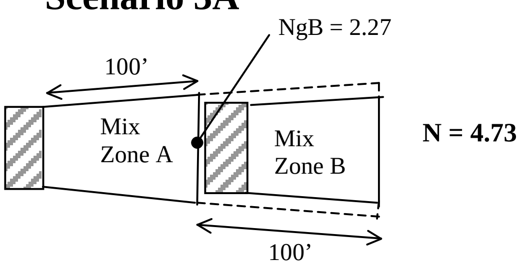
Scenario 2



Scenario 3



Scenario 3A



NONDEGRADATION ATTACHMENT #8

PHOSPHOROUS BREAKTHROUGH ANALYSIS

(updated 4/2000)

SITE NAME: ______________________________

COUNTY: ______________________________

LOT #: ______________________________

NOTES: ______________________________

VARIABLES	DESCRIPTION	VALUE	UNITS
Lg	Length of Primary DF as Measured Perpendicular to GW Flow		ft
L	Length of Primary Drainfield's Long Axis		ft
W	Width of Primary Drainfield's Short Axis		ft
B	Depth to Limiting Layer from Bottom of Drainfield Laterals*		ft
D	Distance from Drainfield to Surface Water		ft
T	Phosphorous Mixing Depth in GW (0.5 ft for coarse soils, 1.0 ft for fine soils)**		ft
Sw	Soil Weight (usually constant)	100.0	lb/ft3
Pa	Phosphorous Adsorption Capacity of Soil (usually constant)	200.0	ppm
#I	Number of Single Family Homes on the Drainfield		

CONSTANTS

PI	Phosphorous Load per Single Family Home (constant)	6.44	lbs/yr
X	Conversion Factor for ppm to percentage (constant)	1.0E+06	

EQUATIONS

Pt	Total Phosphorous Load = (PI)(#I)		lbs/yr
W1	Soil Weight under Drainfield = (L)(W)(B)(Sw)		lbs
W2	Soil Weight from Drainfield to Surface Water = [(Lg)(D) + (0.0875)(D)(D)] (T)(Sw)		lbs
P	Total Phosphorous Adsorption by Soils = (W1 + W2)[(Pa)/(X)]		lbs

SOLUTION

BT	**Breakthrough Time to Surface Water = P / Pt**		years

BY:

DATE:

NOTES: ** Depth to limiting layer is typically based on depth to water in a test pit or bottom of a dry test pit minus 2 feet to account for burial depth of standard*

*** Material type is usually based on test pit. A soil that contains more than 35% silt and clay sized particles is considered fine grained.*

NONDEGRADATION ATTACHMENT #9

CALCULATION OF CUMULATIVE PHOSPHORUS IMPACTS

If any part of two drainfields overlap, as measured in the direction of groundwater flow, cumulative impacts must be addressed. To determine the cumulative effects for two drainfields, the phosphorous equation should be completed using the distance from the upgradient drainfield to the downgradient drainfield as the "distance from drainfield to surface water" in the equation.

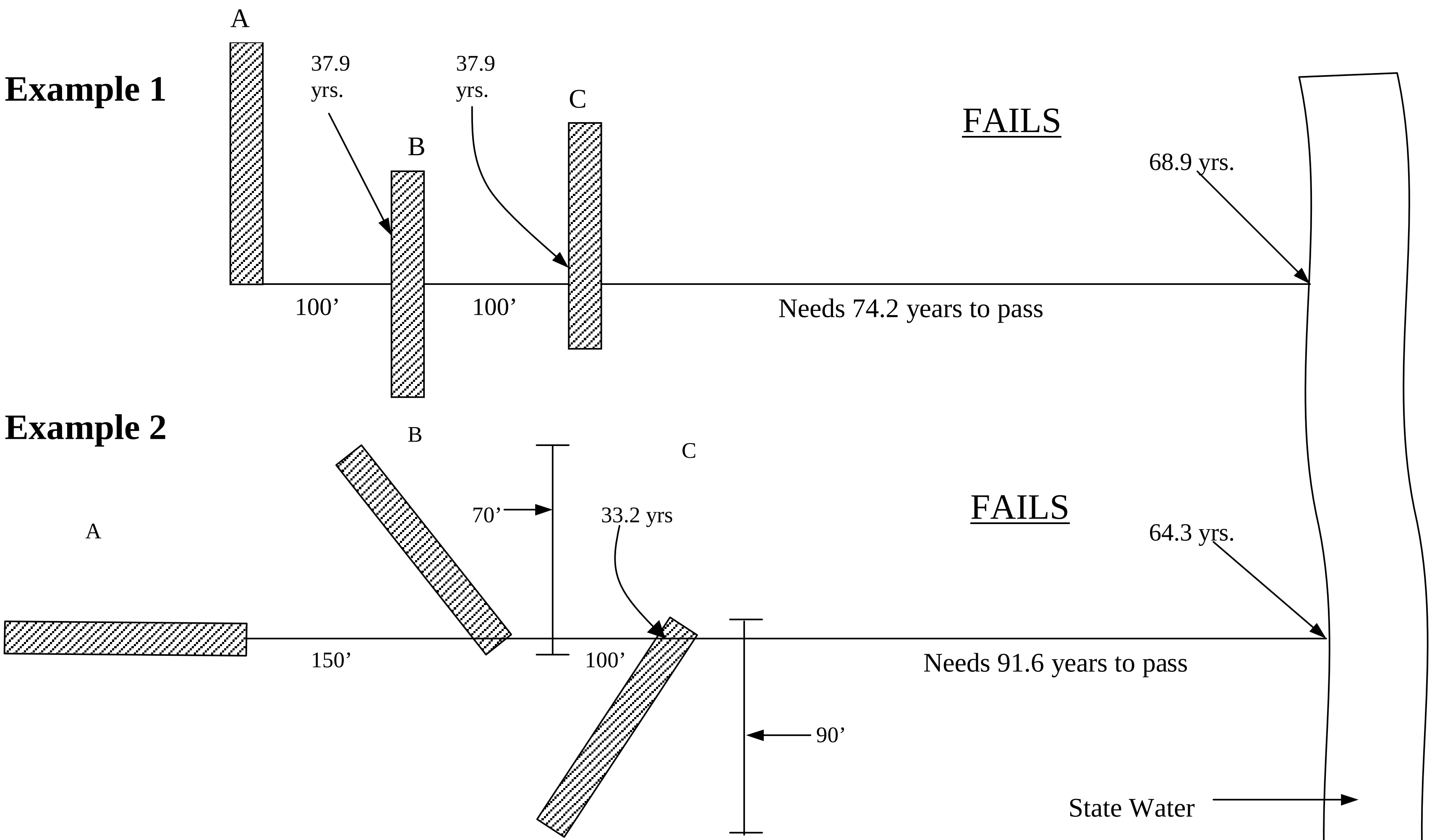
> If P-Breakthrough from the first to the second drainfield **<u>is greater than 50 years</u>**, then there is no cumulative effect and the phosphorus equation should be run as usual from the downgradient drainfield. In this case, the additional difference (the amount greater than 50 years) is NOT applied to the next set of drainfield calculations.
>
> If the P-Breakthrough from the first to the second drainfield **<u>is less than 50 years</u>**, the calculations for the downgradient drainfield must account for the cumulative effects. For example, if the P-Breakthrough from the upgradient to downgradient drainfield is 35 years, then the P-Breakthrough from the downgradient drainfield to surface water must account for the additional 15 years. Therefore, the P-Breakthrough for the downgradient drainfield must be at least 65 years (50 years plus the 15 years leftover from the first drainfield) to surface water to be nonsignificant degradation of state waters.

In EXAMPLE 1 (see following page), the distance between drainfield A and drainfield B is 100 feet and the time to P-Breakthrough is 37.9 years. Because this is less than the 50 year P-Breakthrough required to be nonsignificant, 12.1 years must be added to the P-Breakthrough for the next drainfield (50 years minus 37.9 years). In this example, the P-Breakthrough from drainfield B to drainfield C is the same P-Breakthrough time as A to B. The total shortage P-Breakthrough time for these two drainfields, 24.2 years, must be added to the time for P-Breakthrough for the final drainfield to the surface water, 50 years + 24.2 years. Therefore drainfield C needs 74.1 years to P-Breakthrough to the surface water in order to be determined nonsignificant. In example 1 the P-Breakthrough is 68.9 years and fails in P-Breakthrough.

EXAMPLE 2 (see following page) demonstrates how drainfields that are skewed to the direction of groundwater flow are used in the calculation of cumulative effects.

Remember that P-Breakthrough is calculated to the <u>nearest</u> surface water if the groundwater flow direction was determined by using 1/3 regional topography. If the groundwater flow direction was determined by an acceptable published source or measured, surveyed wells – then the nearest surface water in the <u>direction of groundwater flow</u> is considered for P-Breakthrough.

NONDEGRADATION ATTACHMENT #9a
CALCULATION FOR CUMULATIVE EFFECTS: PHOSPHOROUS BREAKTHROUGH



Depth to groundwater: 6 ft.
Phosphorous mixing depth: 0.5 ft

Direction of Groundwater Flow

Primary Drainfield

NOT TO SCALE

NONDEGRADATION ATTACHMENT #10

SUMMARY OF CATEGORICAL EXEMPTIONS
Please see ARM 17.30.716 for specific details.

Parameter	**≥ 1 acres**	**≥ 2 acres**	**≥ 5 acres**	**≥ 20 acres**
Depth to uppermost aquifer or fractured bedrock	> 100 feet	> 50 feet	> 30 feet	> 20 feet
Distance to surface water	> 300 feet	> 300 feet	> 300 feet	> 300 feet
Background nitrate-N concentration	< 2.0 mg/L	< 2.0 mg/L	< 2.0 mg/L	< 2.0 mg/L
Percolation rate	> 20 minutes/inch	> 30 minutes/inch	> 10 minutes/inch	> 10 minutes/inch
Soil properties throughout upper 8 feet of soil profile	Medium-textured (very fine sandy loam or finer)	Medium-textured (very fine sandy loam or finer)	Medium-textured (very fine sandy loam or finer)	Medium-textured (very fine sandy loam or finer

NONDEGRADATION ATTACHMENT #11

Dilution Equation for Nitrate Trigger Value (0.01 mg/L) ARM 17.30.715 (c)

$$\frac{(Q_D)(C_D) + (Q_L)(C_L)}{Q_D + Q_L} < \text{T.V.} = \text{nonsignificant}$$

Where:

Q_L = Flow rate into (or out of) water body as determined by stream gauge or ground-water flow (Darcy's Law)

C_L = Nitrate concentration of the water body (can typically assume this is zero)

Q_D = Effluent flow rate from drainfield (200 gpd/single family home = 26.7ft^3/day)

C_D = Nitrate concentration of effluent (50 mg/L for conventional septic; 24 mg/L for level II treatment)

********(NOTE: EQUATION IS VALID FOR CONSISTENT UNITS)********

Darcy's Law: Q = (K)(I)(A)

Where:

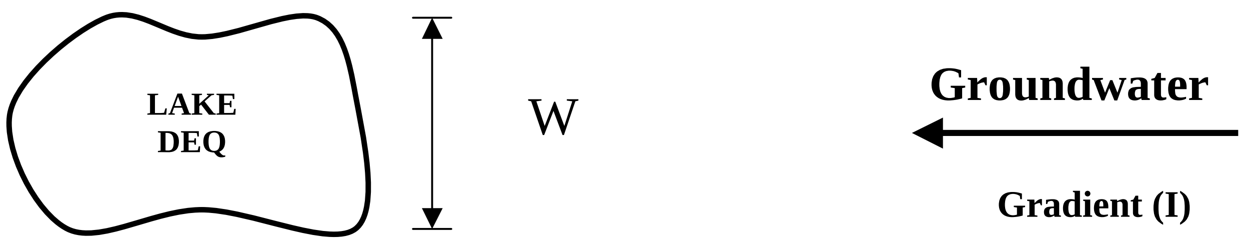
Q =Groundwater volumetric rate (ft^3 /day)
K =Hydraulic conductivity (ft/day)
I =Hydraulic gradient (ft/ft)
A =Area through which groundwater flows ft^2)

NONDEGRADATION ATTACHMENT #12

DARCY'S LAW FOR CALCULATING FLOW VOLUMES

Darcy's Law (Q = K* I*A)

Map



Q = (K) (I) (A)

A = W x D

$$\boxed{Q = (K)\ (I)\ (W)\ (D)}$$

X-Section